TEXAS INSTRUMENTS

12 January, 1995

In Reply Refer to:
232-288-3247
Mail Station 61

Advanced Research Projects Agency (ARPA)
Contracts Management Office (CMO)
Virginia Square Plaza
3701 North Fairfax Drive
Arlington, VA 22203-1714

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ATTENTION: Mr. Donald C. Sharkus

SUBJECT: Liquefied Metal Jet Program (LMJP)

REFERENCE: (a) Contract Number MDA972-93-C-0035
ARPA Order Number 9328/03

ENCLOSURES: (1) Deliverable Item Sequence Number 0002AA, R & D Quarterly Status Report, 15 October 1994 through 15 January 1995
(2) Deliverable Item Sequence Number 0002AA, Program Financial Status Report, 15 October 1994 through 15 January 1995
(3) Deliverable Item Sequence Number 0002AB, Quarterly Technical Report, 15 October 1994 through 15 January 1995

Sir:

Enclosures (1), (2), and (3) are submitted in accordance with reference (a) contract requirements. If you require technical information concerning this submittal, please contact Elwin Whetsel at (214) 995-6424. If you require contractual information, please contact Pamela K. Kidwell at (214) 995-7090.

Sincerely,

Elwin Whetsel

Elwin Whetsel
Program Manager

CC: Pamela Kidwell
Laura Harvey
Program Management
DPRO/TI
DSO - Dr. Richard T. Loda
DSO - Dr. Ira D. Skurnick
DSO - Ms. Claire P. Ri
DTIC - Selections

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19950113 039

Malcolm Baldrige National Quality Award 1992 Winner

LIQUEFIED METAL JET PROGRAM AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)

R&D QUARTERLY STATUS REPORT

REPORTING PERIOD: 15 OCTOBER 1994 THROUGH 15 JANUARY 1995

Sponsored by:

Advanced Research Projects Agency (ARPA)
Contract Management Office (CMO)
Liquefied Metal Jet Program (LMJP)

ARPA Order No. 9328/03

Issued by: ARPA/CMO
Under Contract No.: MDA972-93-C-0035

Deliverable Item Sequence No.: 0002AA

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Prepared by:

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12 January, 1995

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TEXAS INSTRUMENTS

REPORT DOCUMENTATION PAGE

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1. Agency Use Only (Leave Blank)	2. Report Date	3. Report Type and Dates Covered
	January 12, 1995	Qarterly Status Report

4. Title and Subtitle
R & D Quarterly Status Report

5. Funding Numbers
C-MDA972-93-C-0035

6. Author(s) Mr. Nick Dringenburg, Dr. Charles Smith, Mr. Patrick DuBois, Mr. Elwin Whetsel, and Dr. John Priest

7. Performing Organization Name(s) and Address(es)
Automation Robotic Research Institute
7300 Jack Newell Blvd. South
Ft. Worth, TX 76118-7115

Texas Instruments Inc
P.O. Box 655012
Dallas, TX 75265

8. Performing Organization Report Number
0002AA

9. Sponsoring/Monitoring Agency Name(s) and Address(es)
Advanced Research Projects Agency (ARPA)
Contract Management Office (CMO)
Virginia Square Plaza
3701 North Fairfax Drive
Arlington, VA 22203-1714

10. Sponsoring/Monitoring Agency Report Number
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12a. Distribution/Availability Statement
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12b. Distribution Code

13. Abstract (Maximum 200 words)

This report covers the period from 15 October 1994 through 15 January 1995. Our program has initiated test and evaluation of the no lead system, pursued several risk reduction activities, and continued concept design efforts for the copper system.

14. Subject Terms
Liquefied Metal Jet (LMJ)

15. Number of Pages
2

16. Price Code

17. Security Classification of Report	18. Security Classification of this Page	19. Security Classification of Abstract	20. Limitation of Abstract
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LIQUEFIED METAL JET (LMJ) PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)

R&D QUARTERLY STATUS REPORT
DATA ITEM 0002AA
15 OCTOBER 1994 THROUGH 15 JANUARY 1995

1.0 INTRODUCTION

During this reporting period, the program initiated test and evaluation of the no lead system, pursued several risk reduction activities, and continued design efforts for the copper system.

2.0 PROGRESS DURING REPORTING PERIOD

- Produced primitive test coupons demonstrating line and single ball capability.
- Identified and studied problem areas for no lead system reliability including the environmental chamber, nozzle, and material contamination.
  - Redesigned and installed a new environmental chamber to improve process reliability.
  - Started effort to resolve nozzle problems by working with the vendor concerning orifice surface finish and redesigning orifice holder (nozzle).
  - Implemented new material handling procedures to minimize contamination problems.
- Continued testing copper melting and construction material compatibility.
- Completed 60 percent of the conceptual design of the copper system and subsystems.
- Added a contract engineer for three months to insure continued design progress.

3.0 PLANNED ACTIVITIES FOR NEXT REPORTING PERIOD

- Produce no lead test coupons for evaluation.
- Build a physical mock-up of the copper system.
- Continue testing construction materials for copper system.
- Complete detailed design and conduct formal design review of copper system.

4.0 EQUIPMENT PURCHASED OR CONSTRUCTED

Assembled/Constructed

- Revised no lead system environment chamber.

Purchased

- Contract Engineering - Reavill Engineering.
- Oxygen and Moisture Analyzer.

5.0 NOTIFICATION OF KEY PERSONNEL CHANGES

The TI Program Manager, Elwin Whetsel, has accepted another position at TI. His replacement will be named at a later date. Program management responsibilities will be transitioned to the new Program Manager.

6.0 INFORMATION FROM TRIPS, MEETINGS, AND SPECIAL CONFERENCES

- Visited Rautomead and TI Attleboro to gain high temperature melting chamber information and find a potential subcontractor.
- Visited Bird Precision (the current orifice vendor) to discuss nozzle problems.

R&D STATUS REPORT
PROGRAM FINANCIAL STATUS
DECEMBER 1994

	CUMULATIVE TO DATE	AT COMPLETION
	$597,993	$1,127,684

WORK BREAKDOWN TASK ELEMENT		PLANNED EXPEND	ACTUAL EXPEND	% COMPLETE	BAC*	LRE**	REMARKS
MANAGEMENT	1.0	98,109	57,966	59.08%	98,109	98,109	
EQUIPMENT	2.0	814,187	498,579	61.24%	814,187	814,187	
SYSTEM TEST & EVAL	3.0	68,789	0	0.00%	68,789	68,789	
SAMPLE EVALUATION	4.0	107,130	0	0.00%	107,130	107,130	
TECHNICAL TRANSFER	5.0	39,469	0	0.00%	39,469	39,469	
SUB-TOTAL		$1,127,684	$556,545	49.35%	$1,127,684	$1,127,684	
FEE		71,470	41,448	57.99%	71,470	71,470	
MANAGEMENT RESERVE							
UNALLOCATED RESOURCES							
TOTAL		$1,199,154	$597,993	49.87%	$1,199,154	$1,199,154	

*BUDGET AT COMPLETION (BAC) CHANGES ONLY WITH THE AMOUNT OF ANY SCOPE CHANGES. (NOT AFFECTED BY UNDERRUN OR OVERRUN).

**LATEST REVISED ESTIMATE
BASED ON CURRENTLY AUTHORIZED WORK:

(1) IS CURRENT FUNDING SUFFICIENT FOR THE CURRENT FY? (EXPLAIN IN NARRATIVE IF "NO"). YES

(2) WHAT IS THE NEXT FISCAL YEAR'S FUNDING REQUIREMENT AT CURRENT ANTICIPATED LEVELS? 0

(3) HAVE YOU INCLUDED IN THE REPORT NARRATIVE ANY EXPLANATION OF THE ABOVE DATA AND ARE THEY CROSS REFERENCED? NO

REPORT DOCUMENTATION PAGE	Form Approved QMB No. 0704-0188

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1. Agency Use Only (Leave Blank)	2. Report Date January 12, 1995	3. Report Type and Dates Covered Quarterly Technical Report

4. Title and Subtitle
Quarterly Technical Report

5. Funding Numbers
C-MDA972-93-C-0035

6. Author(s) Mr. Nick Dringenburg, Dr. Charles Smith, Mr. Patrick DuBois, Mr. Elwin Whetsel, and Dr. John Priest

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12a. Distribution/Availability Statement
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12b. Distribution Code

13. Abstract (Maximum 200 words)

This report covers the period from 15 October 1994 through 15 January 1995. The program has continued test and evaluation of the no lead system, pursued several risk reduction activities, and continued concept design efforts for the copper system. Significant technical progress has been made for the no lead system. Primitive test coupons have been produced which demonstrate single ball deflection and printing straight lines.

14. Subject Terms
Liquefied Metal Jet (LMJ)

15. Number of Pages
4

16. Price Code

17. Security Classification of Report	18. Security Classification of this Page	19. Security Classification of Abstract	20. Limitation of Abstract
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LIQUEFIED METAL JET (LMJ) PROGRAM
AUTOMATION AND ROBOTICS RESEARCH INSTITUTE (ARRI)
QUARTERLY TECHNICAL REPORT
DATA ITEM 0002AB
15 OCTOBER 1994 THROUGH 15 JANUARY 1995

1.0 INTRODUCTION

This report covers the period from 15 October 1994 through 15 January 1995. The Quarterly Technical Report is organized by the Statement of Work (SOW) listed in Section 5.0 of the proposal as follows:

- Reports and demonstration
- Equipment
- System test and experimentation
- Test coupon evaluation
- Technology transfer.

The program continued test and evaluation of the no lead system, pursued several risk reduction activities, and continued concept design efforts for the copper system. Significant technical progress was made for the no lead system. Primitive test coupons were produced demonstrating single ball deflection and printing straight lines.

2.0 REPORTS AND DEMONSTRATION, SOW 5.1

Summary of Filter Analysis Report - Report on a series of experiments conducted to systematically study the effect that various filtering methods and types of filters have in removing any insoluble particles from molten solder. Several samples of filtered and unfiltered material were taken from a modified LMJ system. These samples were analyzed for particles by examining the solder microstructure using SEM/XEDS analysis. Detailed results are given in the report.

Weekly Progress Reports - Weekly progress reports are now being written.

Trip Report - Report on meetings with Rautomead, Byrd Precision, and Texas Instruments - Attleboro.

Initial Demonstration of No Lead System - Produced single ball and straight line test coupons.

3.0 EQUIPMENT, SOW 5.2

Major program milestones met during this period include:

- Produced simple test coupons demonstrating line and single ball capability.
- Identified and studied problem areas for no lead system reliability including the environmental chamber, nozzle, and material contamination.

- Redesigned and installed new environmental chamber to improve process reliability and incorporate recent findings on H_2O and O_2 content.
- Started effort to resolve nozzle problems by working with the vendor concerning orifice surface finish and redesigning orifice holder (nozzle).
- Implemented new material handling procedures to minimize contamination problems.

- Continued testing copper and construction material compatibility.
- Completed 60 percent of the conceptual design of the copper system and subsystems.

3.1 Fluidizer, SOW 5.2.1

The fluidizer module for the LMJ system converts the solid metal feedstock to liquid. Propelling forces are required to drive the LMJ at the predetermined velocity. The resulting liquefied metal transitions to the droplet generator for subsequent droplet formation.

The no lead fluidizer design continues to operate to specification and performs satisfactorily.

Conceptual design of the fluidizer for the copper system is 60 percent complete. Detailed design of the fluidizer is in process in areas where we have high confidence.

3.2 Droplet Generator, SOW 5.2.2

The proprietary droplet generator for the LMJ system accepts the liquefied metal from the fluidizer and provides the controlled instability required to excite the jet stream into a repeatable droplet formation. The droplets will be charged and continue through an electrostatic deflection field to impact the target at a precise location.

As mentioned in the last report, process reliability problems continue to plague the program. These include stream instability and a lack of consistent droplet formation. Tests show that the problems are due to poor environmental control in the test chamber, nozzle leaks, and material contamination. Design changes were incorporated to correct these problems.

Single ball deflection, a basic capability to generate test coupons, was performed on the no lead system using a 2 mil diameter nozzle.

3.3 Jet/Droplet Stream, SOW 5.2.3

A path for the droplets to be charged and deflected is provided in the design of the system. The path also provides for alternative atmospheres for experimentation.

The size of the droplets was reduced to accommodate the deflection control subsystem. Initially droplets of 4 mil diameter were being attempted using a 2 mil nozzle. Improved material handling, cleanliness, and filtering techniques allowed us to decrease the nozzle diameter to 1 mil and generate 2 mil diameter balls. This improved our ability to direct the ball to the target and will ultimately help generate patterns with better resolution.

The copper system conceptual design is 60 percent complete. Detailed design is in process based on findings from the no lead system and thermal analysis.

3.4 Target Chamber, SOW 5.2.4

The test coupons (i.e., samples) reside in a fixture within a chamber to provide for a controlled inert atmosphere. This chamber provides controlled heat for coupon preheating, optical observation, and instrumentation. In addition to the chamber, a precision motion control system to position the coupon for pattern writing was designed, acquired, and integrated into the LMJ system. A device to catch and collect the unwanted or "guttered" droplets is included in the coupon chamber.

The no lead target chamber is complete and in use. Environmental control is being improved by changing the material of construction from plexiglas to stainless steel. This will eliminate leakage and moisture outgassing with the present structure. The redesigned and reconstructed structure will be complete and installed by January 10. Operational reliability will be improved with this change.

No design work on the copper target chamber is being performed until results from the no lead system testing are available.

3.5 System Control, SOW 5.2.5

System control addresses all items necessary to control and monitor the process. Subtasks include hardware, software, and integration for process control, environmental control, data acquisition, and safety. System control includes personal computers, programmable logic controller, data acquisition software, Computer Aided Design (CAD) data, Network Control program interface, and custom programming. Facility related subtasks include fume handling capabilities, safety systems, and thermal management equipment.

The system control computer for the no lead system was received and installed and is being used. Some problems were identified with the speed of the XY table controller. A design change may be required to increase its speed. In addition, the

control interaction between the positioning system and the deflection system was redesigned after initial testing and will be completed by January 15.

4.0 SYSTEM TEST AND EVALUATION, SOW 5.3

Several system and subsystem tests were conducted including:

- Environmental Control
- System Operation
- Single Droplet Deflection.

5.0 TEST COUPON EVALUATION, SOW 5.4

Test coupons will be generated during the next reporting period. They will be evaluated against the requirements generated by the printed wiring board (PWB) consulting team.

6.0 TECHNOLOGY TRANSFER, SOW 5.5

Several United States manufacturers have visited the lab for technology transfer. An industry day held at the Automation and Robotics Research Institute (where the laboratory is located) resulted in over 100 guest/visitors. Serious discussions are still being conducted with IBM, MPM, General Motors - Delco Electronics, and Indium Corporation of America.